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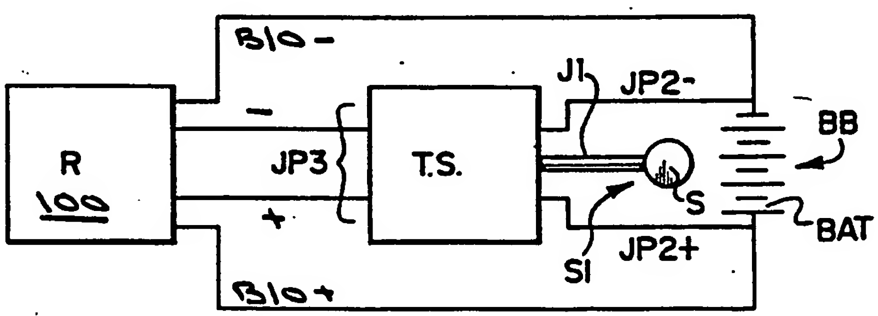

(57) Abstract

A retro-fit temperature compensating device (T.S., JP3, JP2, J1, S) regulates the output voltage (V) of a rectifier (R) or "charger" connected to a rack or bank (B) of serially connected batteries (BAT). The temperature (T) of the battery (BAT) is sensed (S) and the temperature compensating device (TS) regulates the effective voltage (V) applied by the rectifier or charger (R) to the battery terminals (JP2, JP1) according to a pre-selected slope (figure 2) as the manufacturer may have determined from a referenced temperature, generally fixed at 25 °C. The device (TS, JP3, JP2, JP1, S) may be retro-fitted to existing charging units (R) and the device maintains the float voltage on, for instance, a 48V battery string (B) at the manufacturer's recommended charge rate, having a deviation or slope, of 72 mV for every °C of temperature change about the reference voltage 25 °C of the string (B) or single battery (BAT); hence, life expectancy of each battery (BAT) of the string (BB) for the full life term of 10 years may be more adequately achieved.

INTERNATIONAL SEARCH REPORT

International Application No PCT/CA 92/00367

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H02J7/10

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H02J

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category[°]	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	GB,A,2 061 643 (MATSUSHITA ELECTRIC WORKS LTD.) 13 May 1981	1,2
Y	see page 3, line 63 - page 4, line 59	3,4
A	see page 5, line 34 - page 7, line 32; figures 9,14	5
Y	EP,A,0 055 937 (EXXON RESEARCH AND ENGINEERING COMPANY) 14 July 1982	3,4
A	see page 5, line 4 - page 6, line 14; figure 3	5
A	WO,A,8 502 950 (BRAUN AKTIENGESELLSCHAFT) 4 July 1985 see page 1, line 4 - page 6, line 27	1-5

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° Special categories of cited documents :[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

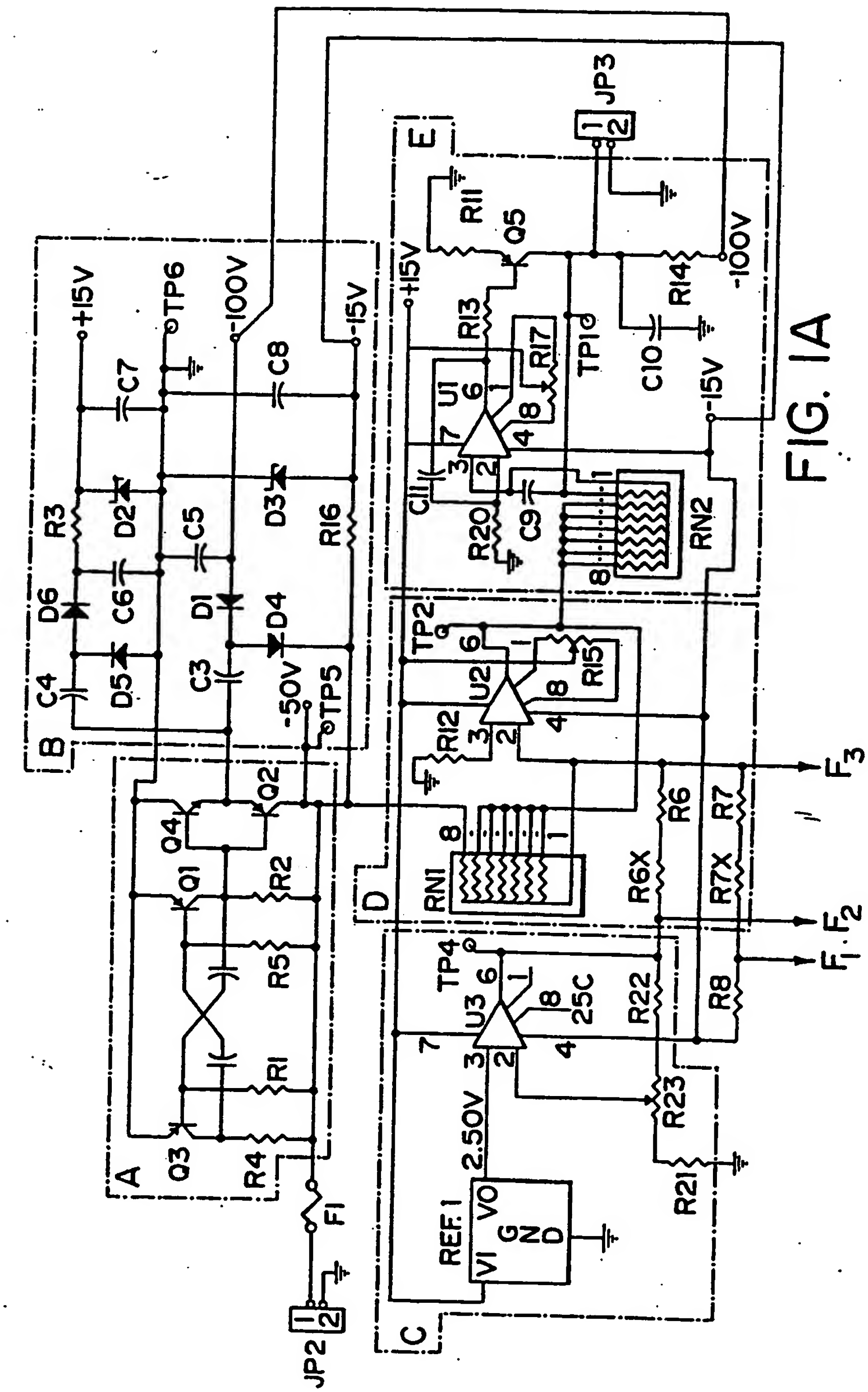
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

1

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
29 APRIL 1993	11.05.93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	SCHOBERT D.A.V.


A
B
C
D
E
JP2
JP3
F1
Q1
Q2
Q3
Q4
Q5
U1
U2
U3
REF. 1
VI
VO
GND
2.50V
25C
RN1
RN2
R1
R2
R3
R4
R5
R6
R6X
R7
R7X
R8
R11
R12
R13
R14
R15
R16
R17
R20
R21
R22
R23
C3
C4
C5
C6
C7
C8
C9
C10
C11
D1
D2
D3
D4
D5
D6
+15V
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TP4
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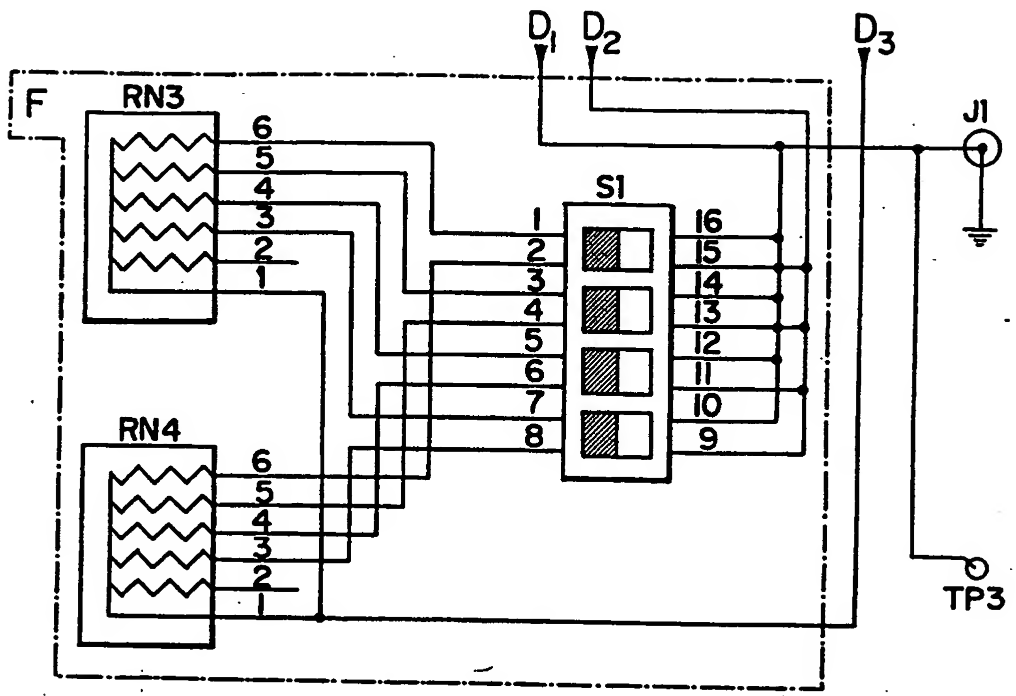
TP6
F_1
F_2
F_3

FIG. 1A


D1
D2
D3
F
RN3
RN4
S1
J1
TP3
1
2
3
4
5
6
7
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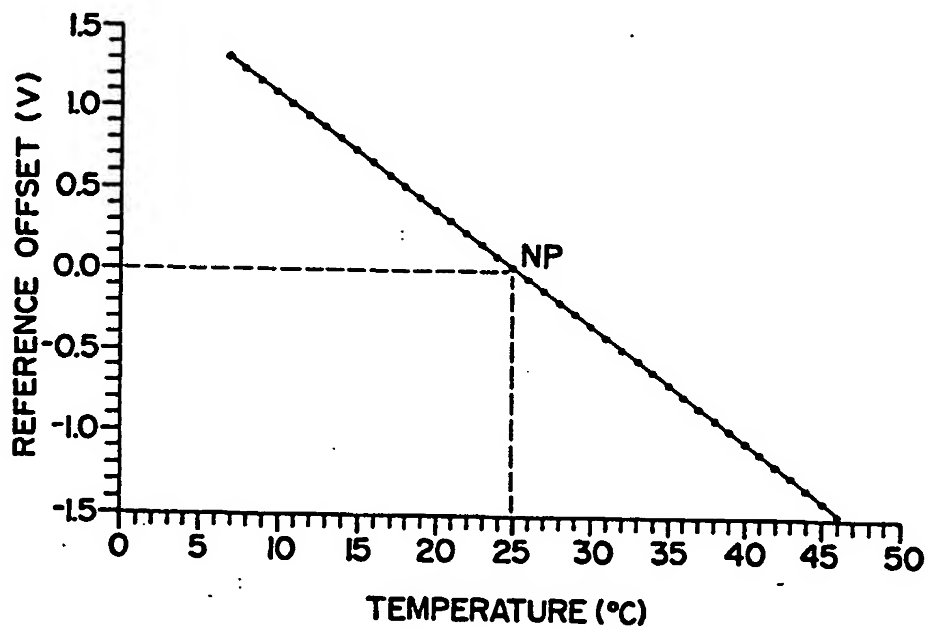
11
12
13
14
15
16

FIG. 1B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1.0
0.5
0.0
-0.5
-1.0
-1.5
NP
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5
10
15
20
25
30
35
40
45
50
TEMPERATURE (°C)

FIG. 2

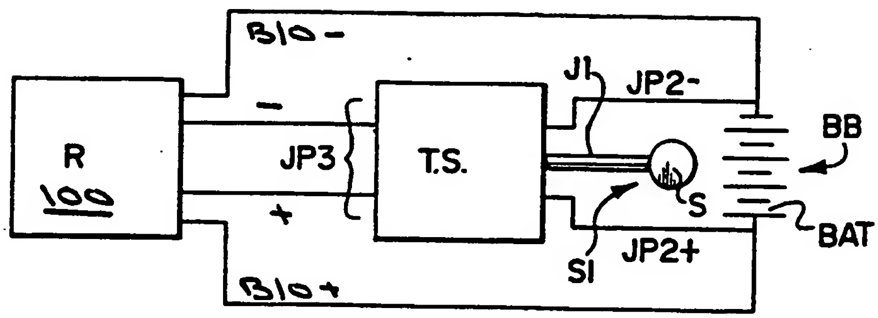

FIG. 3

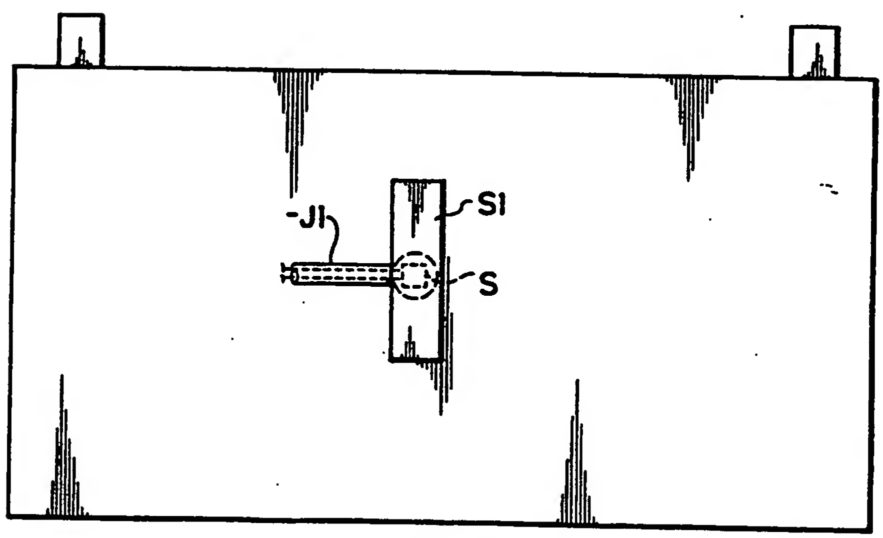

FIG. 4

BATTERY TEMPERATURE COMPENSATING DEVICE FOR BATTERY RECHARGING SYSTEMS

BACKGROUND TO THE INVENTION

Battery manufacturers, in the past few years, have developed sealed, lead-acid maintenance-free batteries as a power source, or prime movers, for the telecommunications industry, telephone switching systems and the like, and in the computer industry for uninterrupted power supplies; they have found their way into automotive battery applications, and also as a future electric source in electric-motored automobiles. It is recommended, by such manufacturers of lead-acid maintenance-free batteries that the optimum operating temperature for the longest life of the battery be maintained at 25°C. The battery life is considerably shortened (and in some cases to less than half of the expected life), if such is not maintained during the charging cycle, or trickling charge cycle, for the batteries.

It is known that the internal resistance of such batteries decreases as the battery temperature rises either as a result of extra current flowing through the battery, or because of the ambient (room) temperature increases. The decreased resistance through the battery allows higher current flows leading to the generation by the battery of more heat. If left unchecked, such condition results in thermal runaway. It is known that such are major problems with batteries which are also used on power back-up systems, as aforesaid noted.

Conversely, overcharging or over-temperature rising will allow such sealed batteries to "gas", and under extreme conditions to explode or bulge or blow out the seal on the battery thus, effectively ending the battery's life. The loss of the integrity of the battery generally causes substantial ancillary damage to equipment and personnel.

ENG, in U.S.A. Patent No. 4,847,547 issued on 11 July, 1989 discloses a battery charger with a V_{bat}

temperature compensation circuit which is integral to the battery charger system itself. It compensates for ambient temperature variations, but not for battery temperature variations.

Similarly, WORTMAN, in U.S.A Patent No. 4,663,580 issued on 5 May, 1987 discloses a sealed lead-acid battery float charge and power supply provided with a pre-determined non-linear temperature co-efficient located within the power supply that provides a pre-determined nonlinear temperature co-efficient by using a linear temperature co-efficient element (a forward biased silicon diode) and a nonlinear temperature co-efficient element (thermistor) in combination.

COOPER et al., in U.S.A. Patent No. 4,667,143 issued on 19 May, 1987 discloses a battery charger having temperature compensated charge rates. The circuitry disclosed is one of a battery charger providing a control circuit for switching the type of regulation in response to the current, voltage and temperature signals, but the temperature signal is one of ambient temperature and not of battery temperature. It is only the battery temperature which affects the internal impedance of the battery during the recharging cycle.

It is an object of the invention therefore to adjust, in response to the battery temperature, the recharging voltage to a battery.

It is a further object of the invention to regulate the voltage on recharge to within 1% throughout the recharging temperature range.

It is a further object of the invention to provide a battery-temperature-compensating device which is able to be retro-fitted to existing battery chargers, hence avoiding the need for expensive replacement of battery charging devices.

THE INVENTION

The invention achieves the foregoing by the use of a temperature-sensing element, preferably an integrated circuit, physically mounted on the battery to sense the temperature of the battery. The same is connected by appropriate electrical leads to a monitoring circuit which proportionately regulates, in response to the temperature of the battery, the voltage applied by a battery charger electrically connected to the battery, whereupon regulation follows along a linear graph, over the preferred operating range of -40°C to +60°C as a preferred linear voltage compensation between the temperatures ranging from 0°C to 50°C at voltages of -2.5 to -4.5 mV/°C/cell (60-108mV/°C/string); but the slope of the linear compensation can be changed depending upon the type of batteries being recharged and the total voltage of the battery pack string.

It can be observed from the foregoing that a realistic summertime day-to-night temperature change of about 15°C will result in the equivalent of a 900-1620mV change in the reference voltage (sometimes called, herein, the "float voltage") that should be effectively applied (negatively) to the battery as it's temperature rises during recharging; and, as is disclosed herein, this is achieved even with existing battery charging units (sub. nom.) rectifiers (R) connected to existing battery recharging systems.

The invention achieves, in response to the actual ambient or current temperature of the battery, during its recharging cycle, a dynamic changing of the recharging voltage applied to the battery terminals by changing the recharging reference voltage or "float voltage", through the range of -1.5 volts to +1.5 volts, as a deviation voltage around the preferred or recommended recharging voltage, for recharging purposes, (the null point) for any given temperature, which generally is the actual recharge voltage, per cell; or,

battery, at the reference temperature for the battery; namely, 25°C.

The invention will now be described by way of example and with reference to the accompanying drawings in which:

Figures 1A and 1B are block and circuit diagrams of the preferred embodiment.

Figure 2 is a typical voltage vs. temperature graph of "compensating" or "float voltages" for a nominal 24V battery string having 24 operating lead-acid cells.

Figure 3 is a circuit diagram, illustrating the outboard compensating system, according to the invention, interconnected between a battery bank (BB), for recharging a plurality of serially connected batteries (BAT), and a battery charger (R) for recharging the same.

Figure 4 is a top plan view, of the sensor housing and in phantom, showing the sensor (S) and connecting cable, in a side elevational view of the sensor adhesively attached to the side of a battery being in the battery bank string of figure 3.

Referring to figure 2 there is plotted, the preferred reference of said voltages (V) depicted, according to battery temperature, in centigrade, as against voltage that is voltage deviating around the meridian which for lead acid batteries of 24 cells is a nominal 48 volts. Where other voltage strings are used, or other different lead-acid batteries of different manufacturers are used, or when batteries of a different type are used, for instance, nickel cadnium battery, the slope of the line passing through the null point (NP) needs to be changed, and this is accomodated by the switches in switch (S1), in figure 1B, switching the resistances (RN3) and (RN4) in or out of the circuit to be described with reference to figure 1B.

Referring to figure 1, it is a composite block float diagram and detail circuit diagram.

The circuit in its present form was designed for use with voltage regulated rectifiers and 24 cell battery strings. The required co-efficient of compensation is about -72mV/C° and is constant with varying temperature. The prototype has a measured co-efficient of 0.71.49mV/C°. The compensator is spliced into the reference leads and takes its power from the battery and its output drives the reference input of the rectifier. The compensator will develop a voltage between input and output terminals, increasing proportionally to the temperature.

Referring to figure 1, JP2 is a connector connected to a battery bank (BB), see figure 3, at one end, and through a fuse element to Block A, an oscillator and output buffer, for generating a square wave of the voltage on JP2. Block A connects to voltage multiplier and regulator, Block B, their combined output feed into summing amplifier Block D which is controlled, in part, by reference voltage generator (C) having a reference means, ref1. From the summing amplifier and the reference voltage generator, some voltage is fed to a slope-selection circuit, Block F. Block F is designed to accommodate various types of batteries requiring different slopes for the purposes of charging, by various selections of the switches, (S1) through (S4) in Block F. Slopes of -60, -72, -84, -96, or, -108 millivolts per centigrade degree can be obtained for the purposes of feedback, as will be described in detail hereafter, see figure 1B. The output from the summing amplifier, Block D, is passed through a voltage amplifier and output buffer (E), for connection to reference leads (JP3), which are eventually connected to the charger (R,100). The differential in voltage at JP3 and JP2, following the chart of figure 2, maintains the voltage for charging, when a battery charger 100 is

connected in accordance with figure 3 to the battery bank (BB), and to the circuit of figures 1A and 1B, to maintain the voltage across the terminals of the battery bank (BB), so as to follow along the linear slope of the graph of figure 2. The connections (JP3) connect directly to the charger (R,100), as seen in figure 3 and provide a feedback of a voltage so that the output from the charger (B/O+-) can change as it is applied to the positive and negative terminal of the battery bank (BB).

Referring to the oscillator and output buffer Block A, the negative terminal of a battery string is connected to plug (JP2) and fed by a fuse (F1), through resistor R4, into the collector of transistor Q3 which, with Q1, acts as switching elements of an astable multivibrator, also consisting of capacitors C1 and C2 interconnected between base and collectors of these transistors. The resistors R1, R2, R4 and R5 are appropriately connected to either base or to collectors so as to establish the multivibrating circuit while the emitters of both transistors are interconnected in the normal fashion. The frequency of oscillation is determined largely by the RC constant of (C1,R5), (C2,R1) and is about, preferably, 8 kHz with this configuration. Transistors Q2 and Q4 form a complementary push-pull buffer, driven by Q1 of the multivibrator aforesaid described, since the bases of Q2 and Q4 are interconnected, as are the emitters. The collector of Q4 is connected to the emitters of the multivibrator Q3 and to the collector resistor R4. Thus, the -50 volt battery input, from connector JP2, is chopped into a squarewave between 0 volts and -50 volts with a frequency of about 8kHz.

Referring to the voltage multiplier and regulators Block B, there are two voltage multipliers and both are driven by the oscillator and Q4-Q2 buffer of Block A. The first voltage doubler is an inverting doubler consisting of capacitors C4, C6 and serially connected

diodes D5 and D6. The capacitor C4 has its other lead connected to the output of the oscillator and buffer Block A, as noted. The output of this inverting doubler consists of +50 volts and is passed through resistor R3 to supply current to a reversed bias Zener diode D2, fixing the reference voltage output thereat, because of filter capacitor C7 which is parallel to the Zener, at +15 volts. This now acts as the positive part of the power supply for the operational amplifiers of figure 1.

Within Block B is a second voltage multiplier that in fact is a doubler and has its output voltage referenced at twice the battery voltage or approximately -100 volts DC. It consists of capacitor components C3 and C5 and series diodes D4 and D1, wherein the capacitor C3 is connected between the junction of the two diodes to the oscillator and output buffer Block A and to the common lead of capacitor C4. The cathode of the diode D4 is connected through series resistor R16 to the cathode of Zener diode D3 whose cathode is connected in series to Zener diode D2 and is in parallel to a filter capacitor C8 whereby a common reference voltage of -15 volts is developed along the anode side of Zener D3 to become the negative part of the power supply from the remainder of circuitry of figure 1. A doubling of voltage takes place at the cathode side of diode D1 so that the output voltage thereat is -100 volts. The 100 volts is used to supply power to the output amplifier stage Block E.

Block C is a reference voltage generator. It consists of a stable reference voltage element ref1 having an output of 2.5 volts to operational amplifier U3. The other input of the operational amplifier U3 is connected through a potentiometer R23 in series, at one end, to resistor R21 and ground; the other end of the potentiometer, through resistor R22 is connected to the output of the operational amplifier U3. The potentiometer R23 is used to adjust the voltage of the

output, at pin 6 of the operational amplifier U3 and to "pad out" any errors caused by component tolerances used. Preferably, the output voltage of the operational amplifier U3 is nominally at +2.98 volts. With a probe temperature at 25°C which is connected to point J1, the output of the operational amplifier U3, is adjusted by R23 so that there is no voltage difference between input and output terminals JP2 and JP3 of figure 1.

Referring to figure 3, a temperature sensing element, S, such as a LM335, being an integrated circuit, is mounted on the physical surface of a battery BAT, such that the sensing element S is not subjected to any air currents circulating about the battery BAT. The sensing element S has an output linearity proportional to temperature with a slope of 10 millivolts per degree Celsius, for the lead-acid batteries. At 25°C, the output is approximately 2.98 volts. The sensing element is driven from the negative power supply; -15 volts, of the voltage multiplier regulator Block B so that the output thereof is always negative with respect to the circuit ground of the compensator of figure 1. The output of the reference voltage generator Block C feeds into summing amplifier, Block D, which has an operational amplifier U2 and a bank, RN1 is provided for a plurality, 7 in number, of resistive inputs in order to provide various slopes, for various battery manufacturers' published specifications of slope. The summing amplifier has three weighted inputs, one of which is the 2.98 volt reference from U3, serially connected through input resistor R6 to provide a forward gain of 1.2 for U2. The output from the temperature-sensing element, or temperature sensor TSE, which is -2.98 volts at 25°C is connected to the outer input through resistor R7 with a gain of 1.2. The negative terminal of the battery is connected to the third input, from JP2 is connected to pin 8 of resistor network RN1 for a gain 1/6. A gain of 1.2 for the reference REF1

and the temperature sensor TSE will cause battery voltage to vary -72 millivolts per °C and will be a normal rest position. However, some batteries, because of their manufacture, may require different slopes. To allow for slope variation, reference offset to °C (figure 2), a network of resistors comprising any or all of the elements RN3 and RN4, slope selection circuit, Block F, can be connected in parallel with resistor R6 and also with resistor R7 respectively, using the various switches located in switch S1 so that various slopes in the following ranges can be achieved; -60, -72, -84, -96, and -108 millivolts per °C. The feedback resistor for the operational amplifier U2 is in fact, parallel resistors 1 through 6 of RN1 which is connected to the output terminal 6 of the operational amplifier U2. Because the resistance and also the temperature co-efficient of the resistive elements are close, a fairly accurate and stable gain for this operational amplifier U2 can be selected for battery strings of selected voltage ranges, i.e., 36 volts, 24 volts, or 12 volts by selecting the resistors of RN1 in or out of the circuit.

Referring to voltage amplifier and output buffer, Block E, the same consists of an operational amplifier U1, and transistor Q5, operating as a Class "A" amplifier, has the base of Q5 connected through resistor R13 to the output of operational amplifier U1, providing temperature-compensated voltage to the reference terminals of the battery charger connected to JP3. This circuit has a gain of 6, which is set by using a single resistive network RN2. U2 is a low offset type and thus, the trimming of potentiometer R17, connected between terminals 1, 8 and 7 of the operational amplifier U1, is not normally needed.

EXAMPLE COMPONENT LIST (Figures 1A, 1B, 3, 4)

C1	3 nF	Q1	MPSA92	R14	750 Ω, 5W
C2	3 nF	Q2	MJE350	R15	20K Ω
C3	22 μF	Q3	MPSA92	R16	2.4K Ω, 3W
C4	10 μF	Q4	MJE340	R17	20K Ω
C5	22 μF	Q5	MJE340	R20	1.87K Ω
C6	10 μF	R1	390K Ω	R21	10K Ω
C7	10 μF	R2	2.2K Ω	R22	1.87K Ω
C8	10 μF	R3	2.4K Ω	R23	1K Ω
C9	100μF*	R4	10k Ω	RN1	120K Ω
C10	10μF*	R5	390K Ω	RN2	120K Ω
C11	1 nF	R6	20K Ω	RN3	100K Ω
D1	1N4004	R7	20K Ω	RN4	100k Ω
D2	1N4744A	R8	12K Ω	U1	OP07
D3	1N4744A	R11	120 Ω	U2	OP07
D4	1N4004	R12	3.3K Ω	U3	OP07
D5	1N4004	R13	2K Ω	REF1	MC1403
D6	1N4004	S1	Grayhill Switch 7804	F1	1A VAC

* (or not used)

WE CLAIM:

1. A battery temperature compensating assembly (TS) for regulating the charge to a battery (BAT, BB) with a charging voltage (V), while monitoring the temperature (T) of the battery (BAT) during recharging, characterized by means for sensing (S) the temperature (T) of the battery (BAT) being charged and for controlling voltage (V,figure 2) and hence, the charging current to the battery (B) in conformity with the disclosure herein.

2. A method of regulating the voltage (V) applied to a battery (BAT) when the battery (BAT) is being recharged characterized by the steps of:

(a) measuring the temperature (T) of the battery (B) during recharging; and,

(b) adjusting (T.S., JP3, JP2, JP1) the voltage (V) applied to the terminals (JP2-, JP+) of the battery (BAT) in negative conformity (figure 2) with the temperature (T) of the battery (BAT) whereby to keep a predetermined charging current flowing through the battery (BAT), irrespective of the battery transient temperature (T).

3. The battery compensating assembly (TS), as claimed in claim 1, wherein the temperature compensating assembly (TS) additionally comprises:

(a) an oscillator and buffer module (A) with input from a battery connector (JP2) that provides output to;

(b) a voltage multiplier and regulator module (B) providing operating voltages;

(c) a reference voltage generator module (C) including a reference sub-module (REF1) and an operational amplifier (U3) generating an operating voltage to;

(d) a summing amplifier module (D) including a resisitve bank (RN1) and operational amplifier (U2) connected to;

(e) a voltage amplifier and output buffer module (E) having an input from the summing amplifier module (D) to an operational amplifier (U1) providing for a given gain in accordance with the resistance (RN2) across its inputs (U1-3,2) the output of which passes through a transistor (Q5) to provide a voltage to connector (JP3) connect with its respective negative and positive terminals to a battery recharging unit (R,100).

4. The battery temperature compensating assembly (TS), as claimed in claim 3, including means (RN3, RN4) for changing the resistance across the summing amplifier module (D) and hence, the slope (figure 2) of the compensation voltage, selectively, by a predetermined amount, according to the type of the batteries used, selected from lead-acid batteries and nickel-cadnium batteries, and the number of batteries (BAT) in a recharging battery bank (BB).

5. The battery charging assembly, as claimed in claim 4, wherein the co-efficient is about -72mV/C°.

AMENDED CLAIMS

[received by the International Bureau on 25 August 1993 (25.08.93); original claims 1-5 replaced by amended claims 1-8 (3 pages)]

1. A battery temperature compensating assembly (TS) for regulating the charge to a battery (BAT, BB) with a charging voltage (V), at terminals (JP2- JP2+) of the battery (BATBB) while monitoring the temperature (T) of the battery (BAT) during recharging, characterized by means for sensing (S) the temperature (T) of the battery (BAT) being charged and for controlling voltage (V,figure 2) at the terminals (JP2- JP2+) and hence, the charging current to the battery (B) in conformity with the disclosure herein.

2. A method of regulating the voltage (V) applied to a battery (BAT) when the battery (BAT) is being charged, in either full recharge of float charge mode and to inhibit overheating of the battery (BAT), during recharge, characterized by the steps of:

(a) measuring the temperature (T) of the battery (B) during said recharging; and,

(b) adjusting (T.S., JP3, JP2, JP1) the voltage (V) applied to the reference terminals (B/O-, B/O+) of the battery charger (R,100) in negative conformity (figure 2) with the temperature (T) of the battery (BAT) whereby to cause a predetermined change in voltage to be applied to the battery (BAT) and hence, a relative change in the current flowing through the battery (BAT), irrespective of the battery transient temperature (T).

3. The method as claimed in claim 2, wherein the temperatures (T), that is sensed, is that of the outside skin of the battery (BAT).

4. The battery compensating assembly (TS), as claimed in claim 1, wherein the temperature compensating assembly (TS) additionally comprises:

(a) an oscillator and buffer module (A) with input from a battery connector (JP2) that provides output to;

(b) a voltage multiplier and regulator module (B) providing operating voltages;

(c) a reference voltage generator module (C) including a reference sub-module (REF1) and an operational amplifier (U3) generating an operating voltage to;

(d) a summing amplifier module (D) including a resistive bank (RN1) and operational amplifier (U2) connected to;

(e) a voltage amplifier and output buffer module (E) having an input from the summing amplifier module (D) to an operational amplifier (U1) providing for a given gain in accordance with the resistance (RN2) across its inputs (U1-3,2) the output of which passes through a transistor (Q5) to provide a voltage to connector (JP3) connect with its respective negative and positive terminals to a battery recharging unit (R,100).

5. The battery temperature compensating assembly (TS), as claimed in claim 4, including means (RN3, RN4) for changing the resistance across the summing amplifier module (D) and hence, the slope (figure 2) of the compensation voltage, selectively, by a predetermined amount, according to the type of the batteries used, selected from lead-acid batteries and nickel-cadmium batteries, and the number of batteries (BAT) in a recharging battery bank (BB).

6. The battery temerature compensating assembly (TS), as claimed in claim 5, wherein the slope co-efficient (Fig. 2) is about -3mV/C°/cell.

7. The battery charging assembly (TS) as claimed in claims 1, and 4 through 6, characterized in that the assembly (TS) is discrete from a voltage supply (R) and

is characterized in having leads adapted for connection to battery terminals (JP2-, JP2+) on the one hand, and to the direct current voltage supply (R), on the other hand (JP3-, JP3+), the terminals (JP2- and JP2+), being in parallel with the output voltages respectively (B/O-, B/O+) of the voltage supply (R).

8. The battery compensating assembly (TS), as claimed in claim 1 and 4 through 7, wherein the temperature sensing means (S) is affixed to the outside skin of the battery (BAT).